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Nobel EUV Sources for Photolithography

- Methodological Application -

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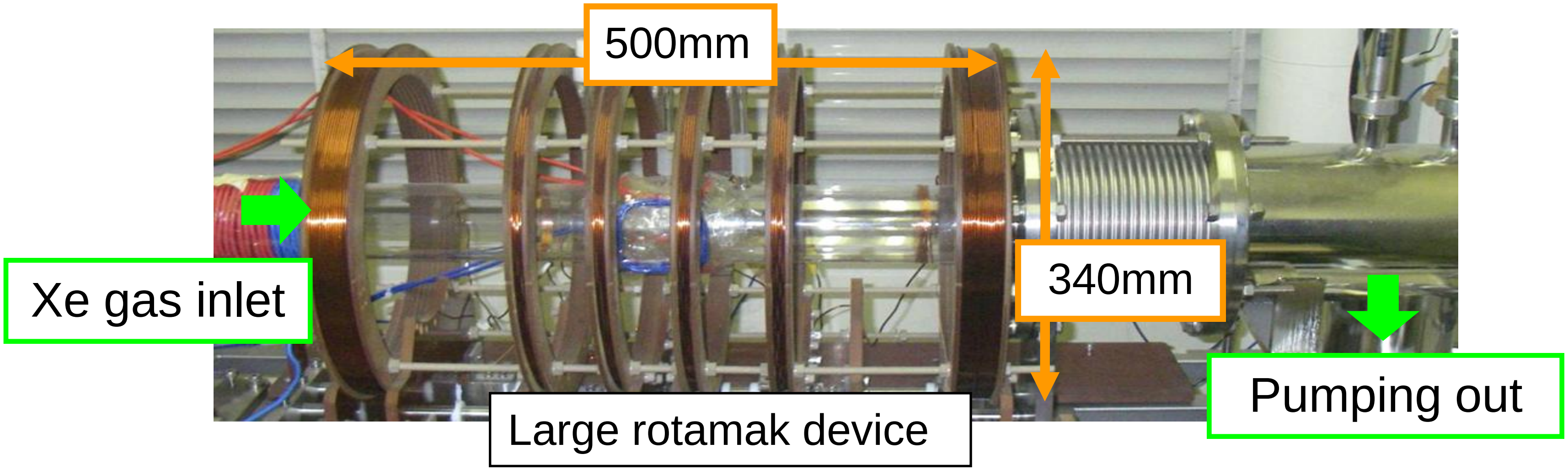
Experimental Results of EUV Light Sources

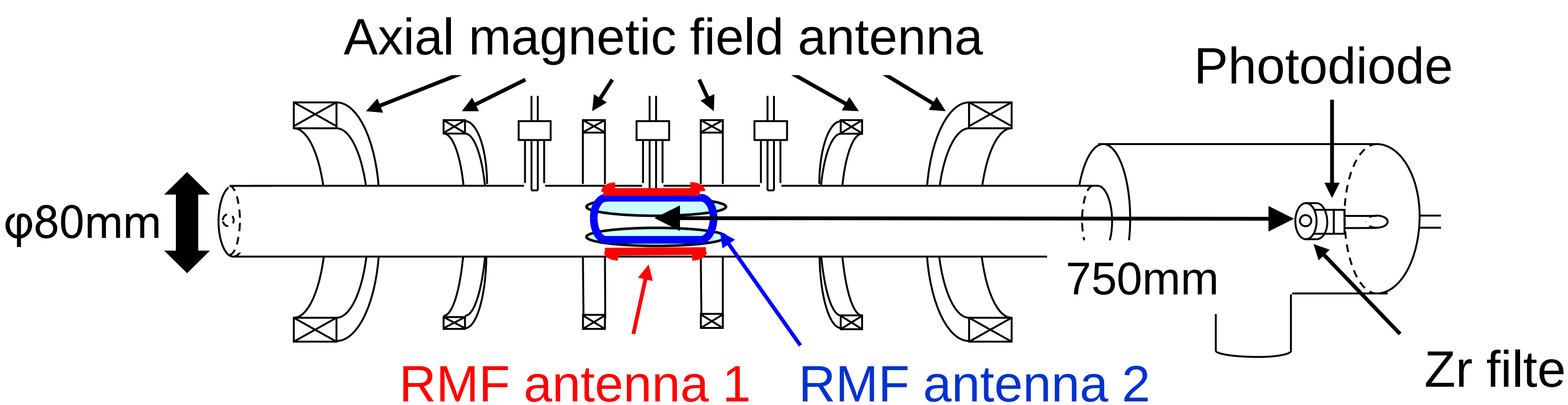
Two approaches to produce EUV for the lithographic and metrological application are studied.

- RMF Discharged Plasma
- Microwave Discharged Plasma

- Both of the plasma are produced by the electrodeless discharge.
- No “debris” are produced.

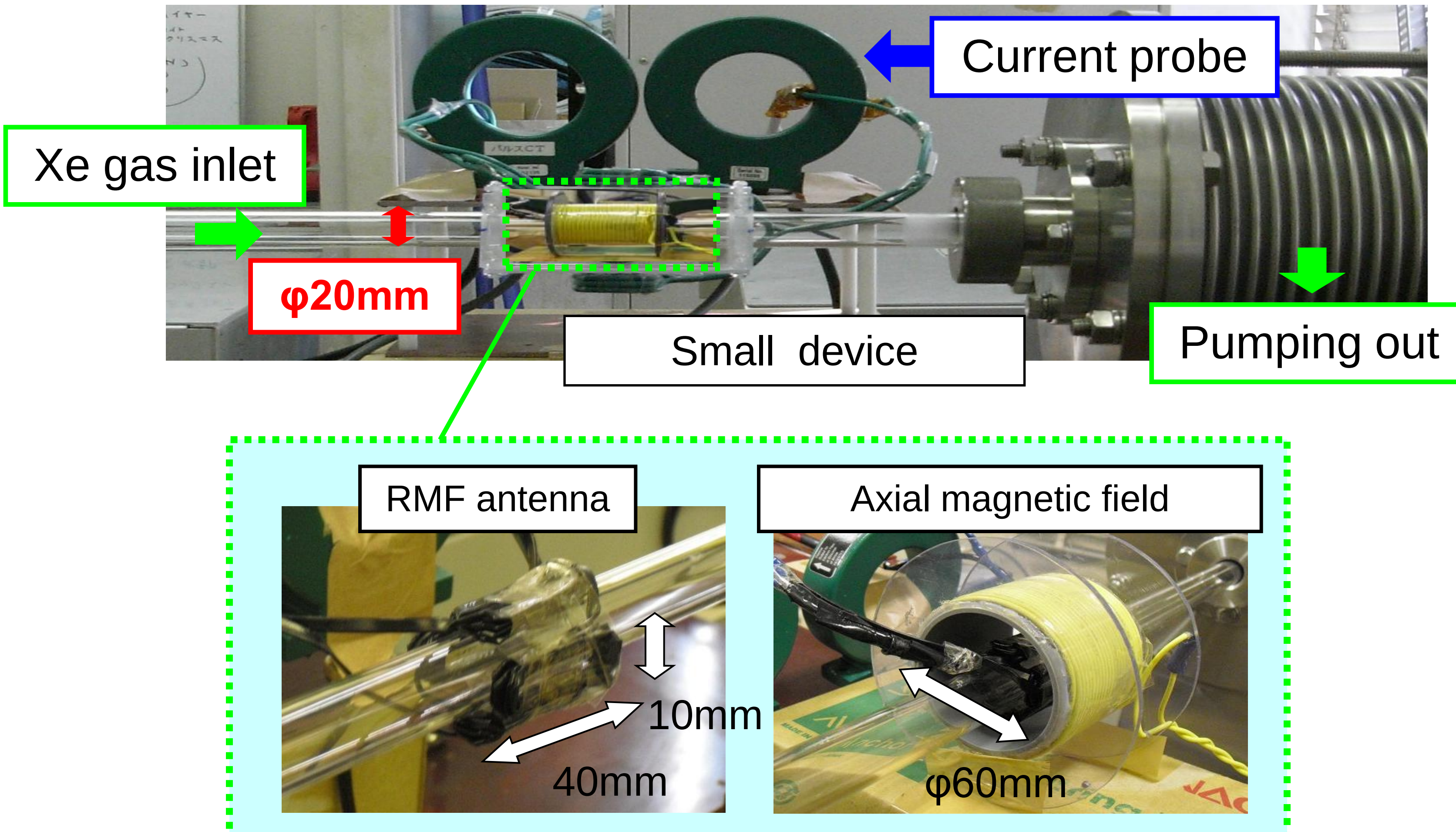
RMF Discharged Plasma in Previous Device



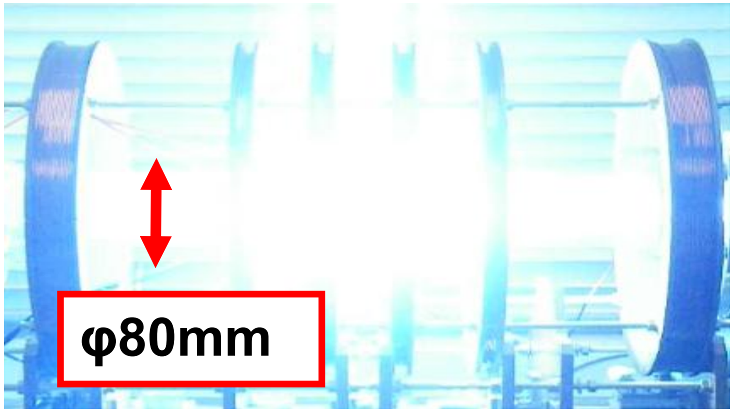


Smaller Device

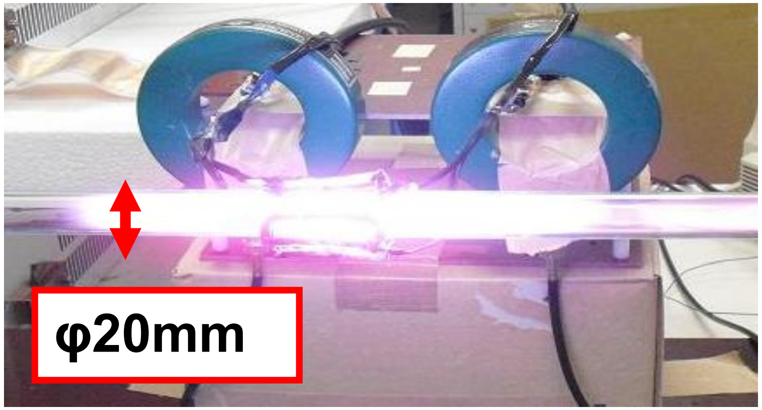
Vacuum tube;φ80mm→φ20mm



Comparison of Discharge Between Large and Small Devices



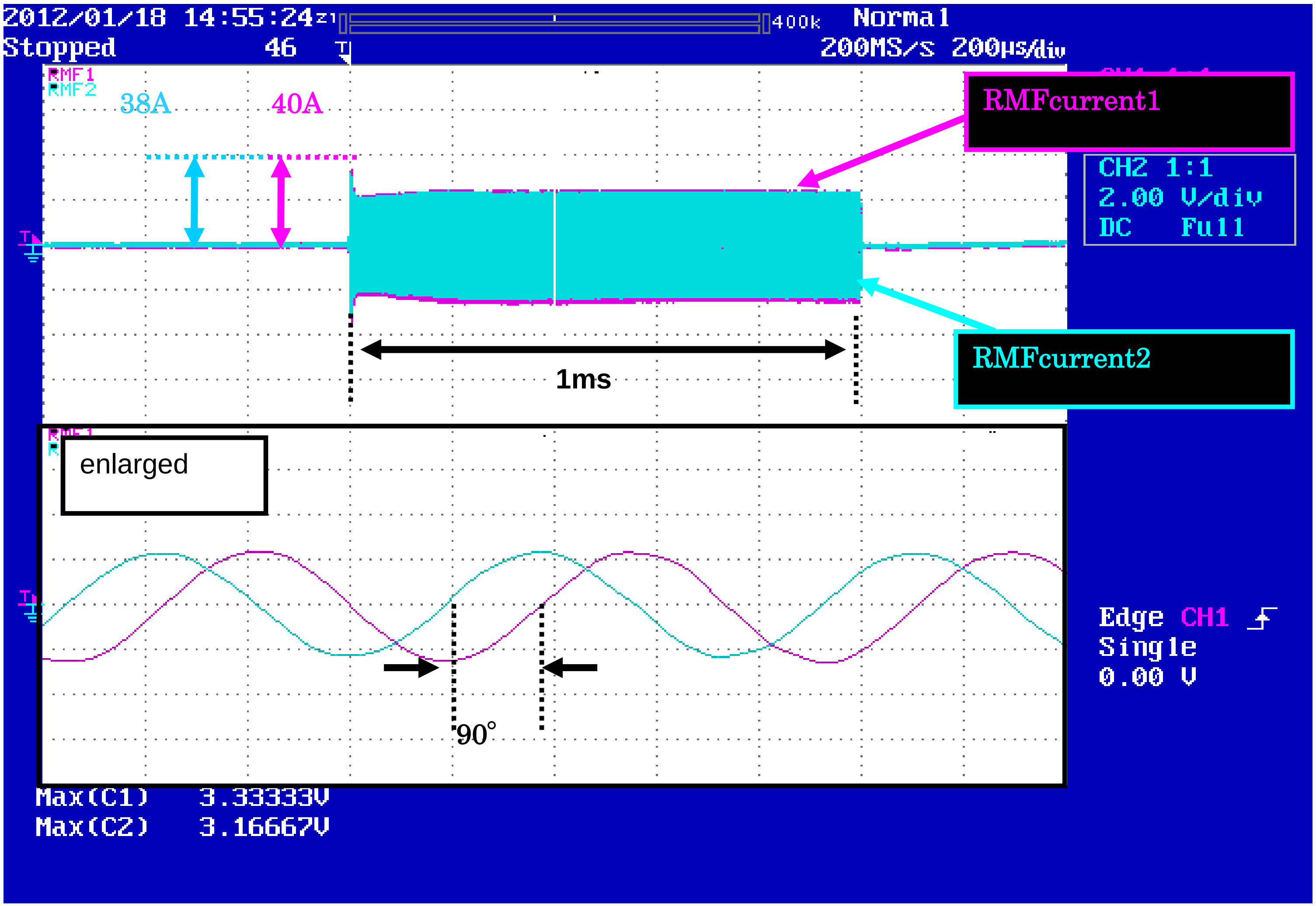
Large



Small

	Large rotamak	Small rotamak
Diameter of vacuum tube	80mm	20mm
Frequency	200kHz	13.56MHz
Input power	50kWx2	5kWx2
EUV power	66W	14W

Wave Form of RMF Current



Discharge Mechanism by 13.56 MHz RMF

Strong Axial Electric Field Production

Rotating Magnetic Field;

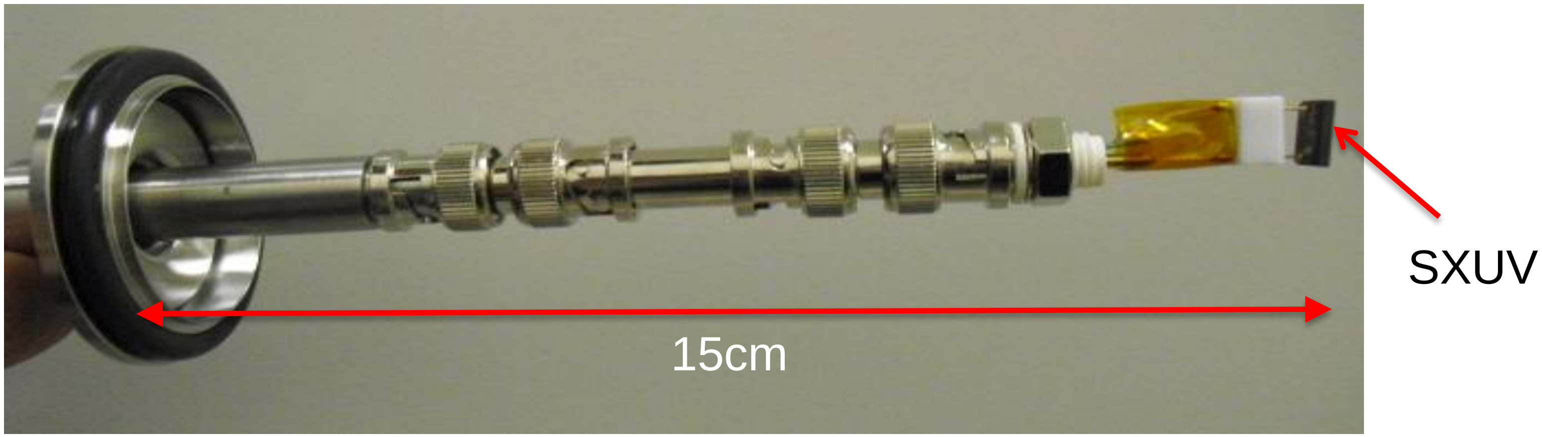
$$B_r = B_\omega \cos(\omega t - \theta)$$

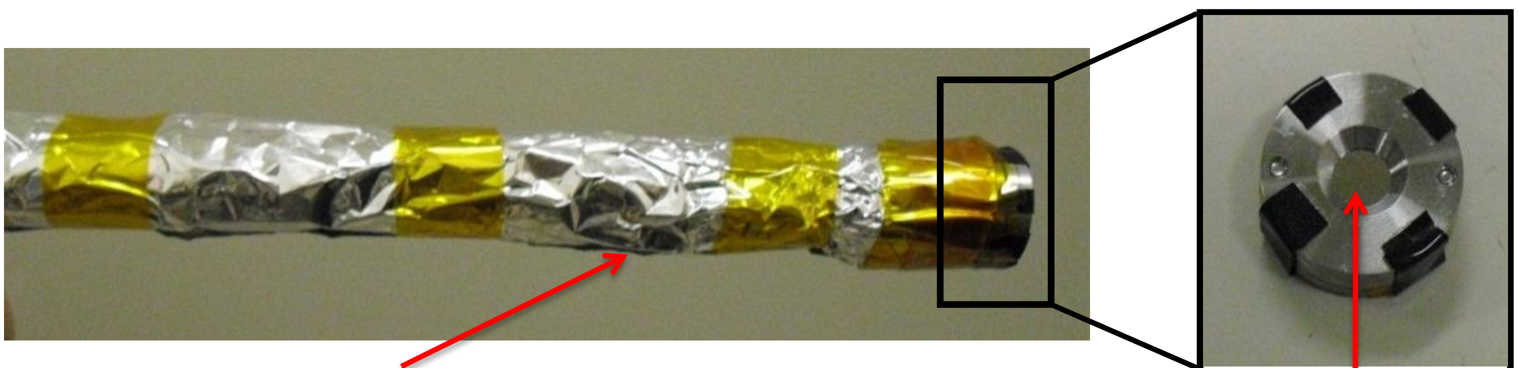
$$B_\theta = B_\omega \sin(\omega t - \theta)$$

$$\frac{\partial \boldsymbol{B}}{\partial t} = -\, rot\ \boldsymbol{E}$$

$$\boxed{E_z = r\omega B_\omega \sin(\omega t - \theta)}$$

Setting of Photodiode with Zr Filter

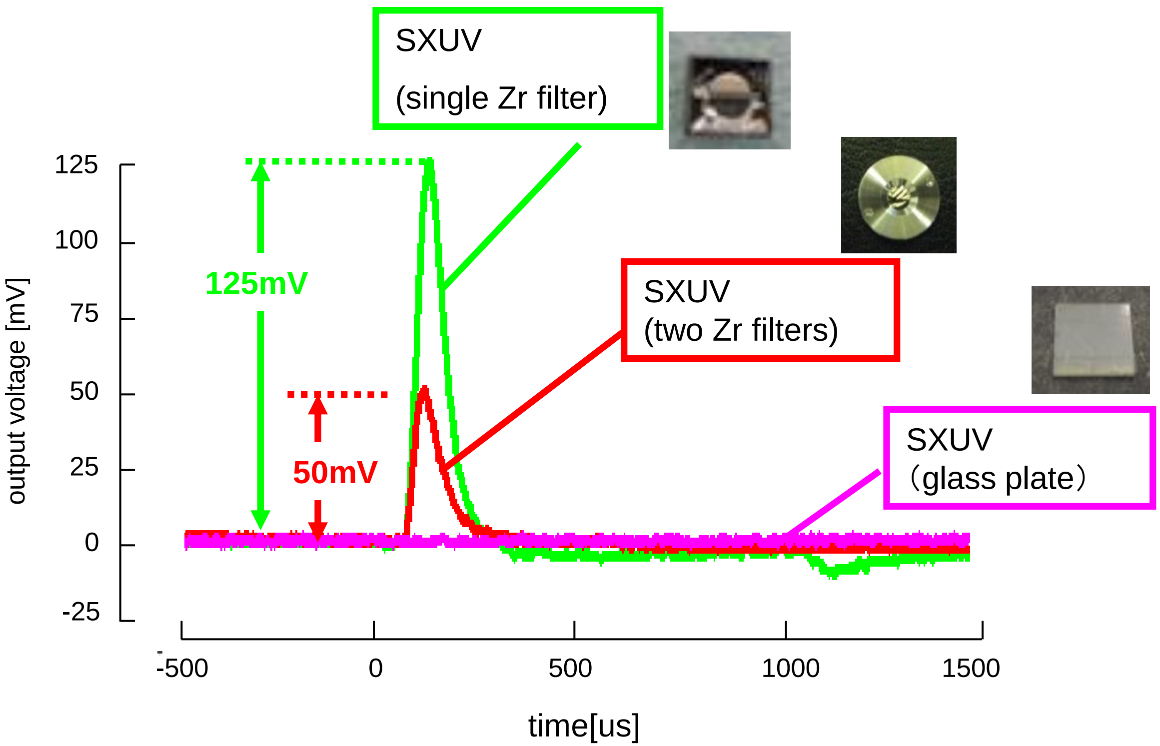


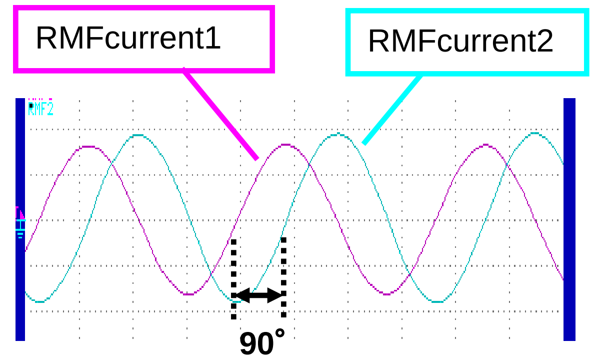


Aluminium foil for plasma shielding

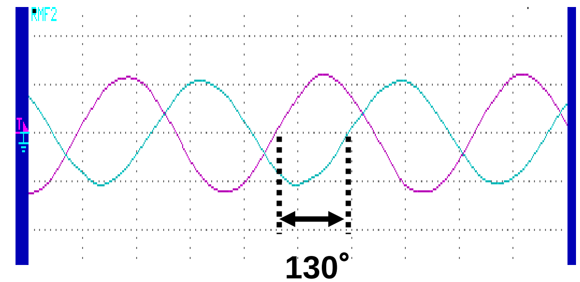
Zr filter

Signals of Photodiode of Single, Double Zr Filters and Glass Plate



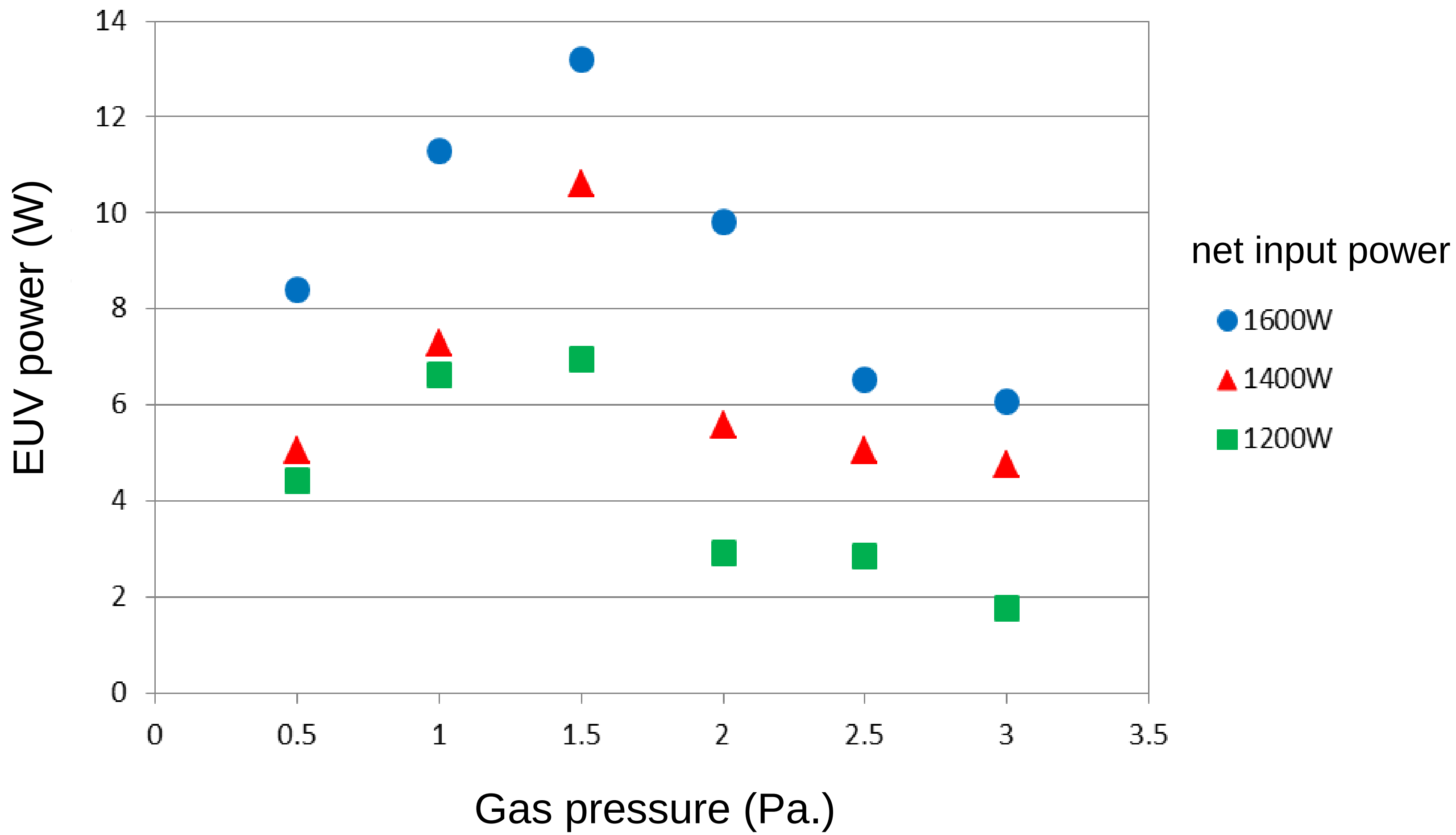


Before Plasma Production



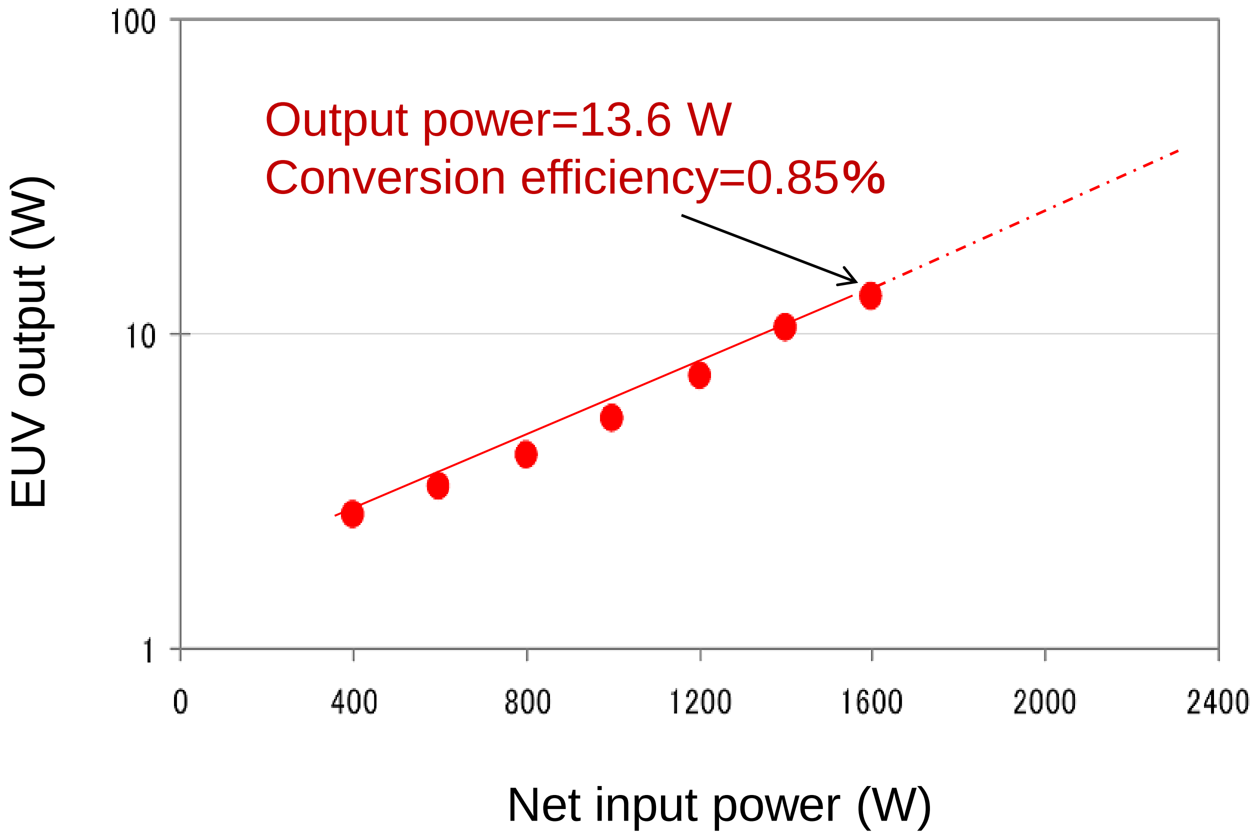
After Plasma Production

EUV Output vs. Xe Gas Pressure



EUV Output Power vs. Input Power

Net input power = Input power - Reflection power



Microwave Discharged Plasma EUV Experiment

Features：

- 2.45 GHz Microwave
- TM010 Mode Resonance Cavity with High Q value
- Plasma of 1-1.5 mm in the Diameter

Production of EUV by Using Microwave Plasma

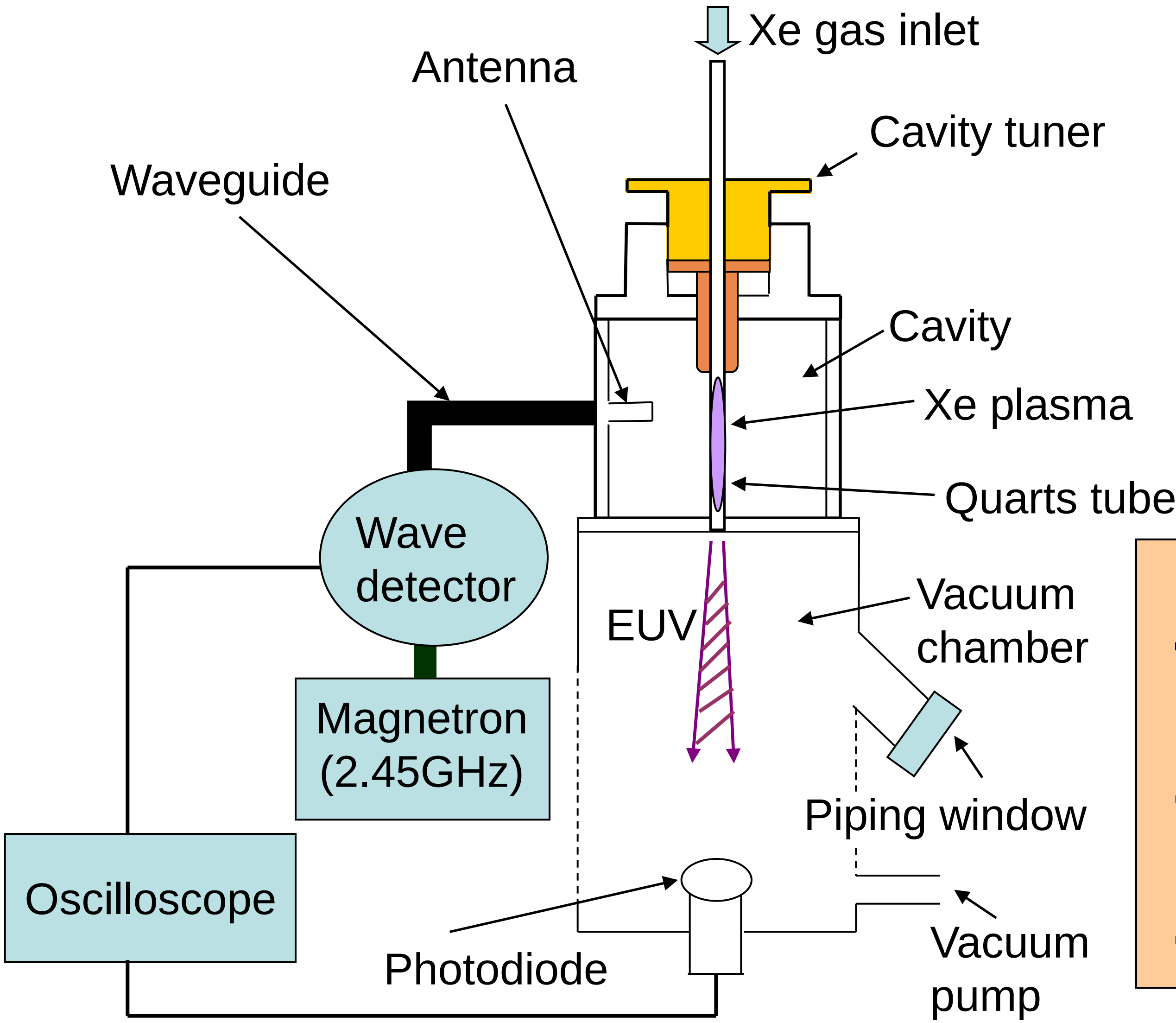
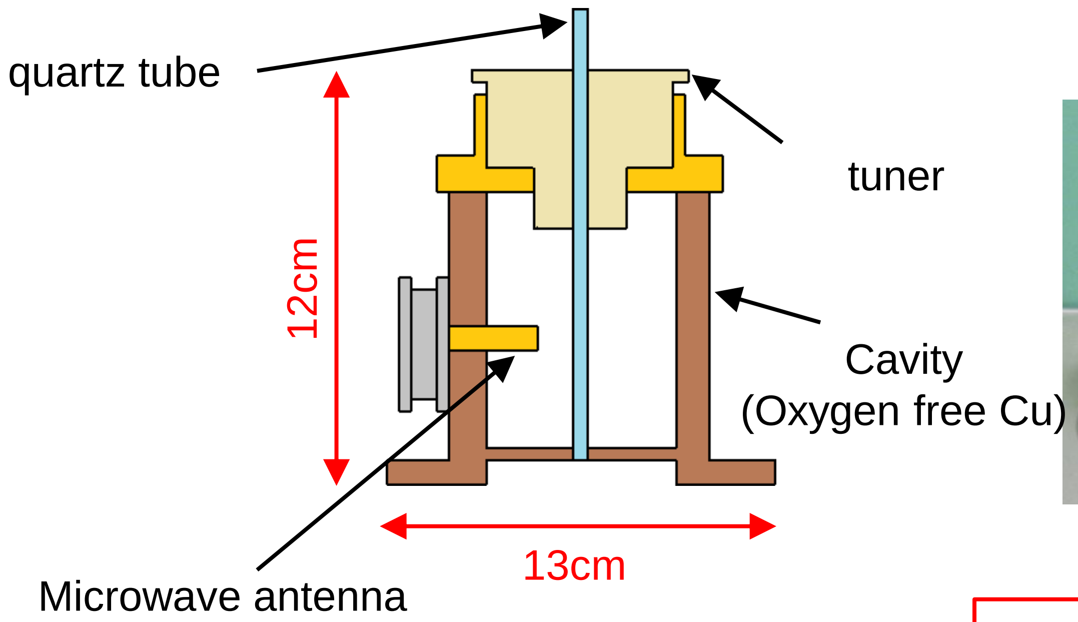


Photo of plasma

- Advantage -

- Electrodeless plasma production
- Pulse plasma formation (～1kHz)
- Small size

Resonant Cavity



Q-value: Cavity Q= 8,600(theory)

Loaded Q=1,476(Exp.)

Magnetron output: 500 W (Max)

Repetition: 1kHz

Duty: 6-100%

Electro-Magnetic Field of TM010 mode

$$E_r = 0 \qquad H_r = 0$$

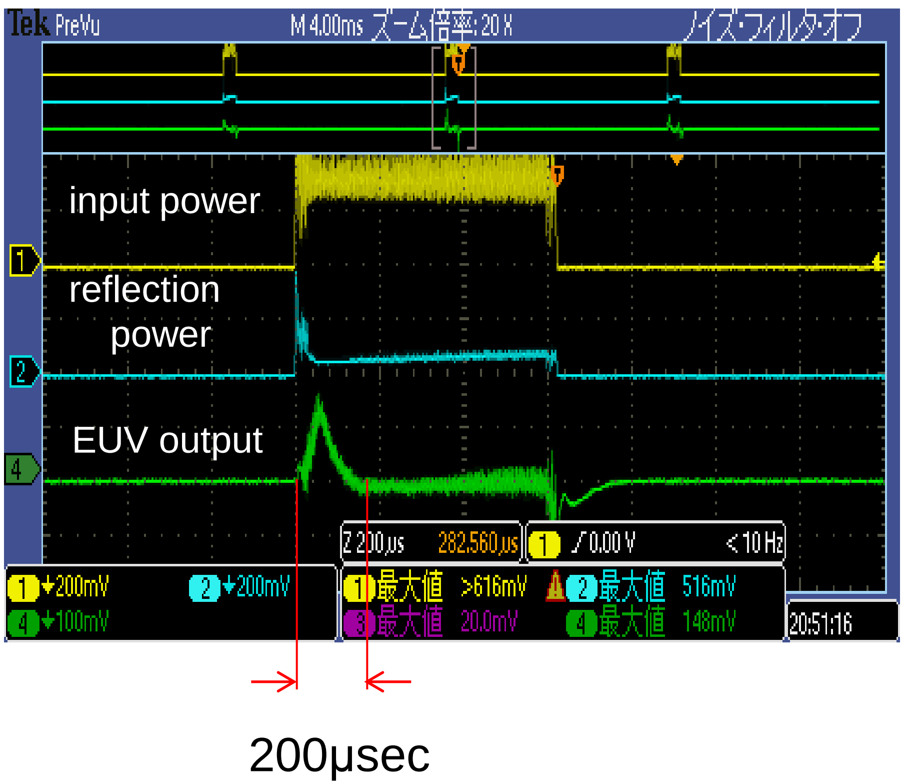
$$E_\theta = 0 \qquad H_\theta = \frac{i\omega\varepsilon}{k^2}\frac{j_{01}}{R}AJ_0\left(\frac{j_{01}}{R}r\right)$$

$$E_z = AJ_0\left(\frac{j_{01}}{R}r\right) \qquad H_z = 0$$

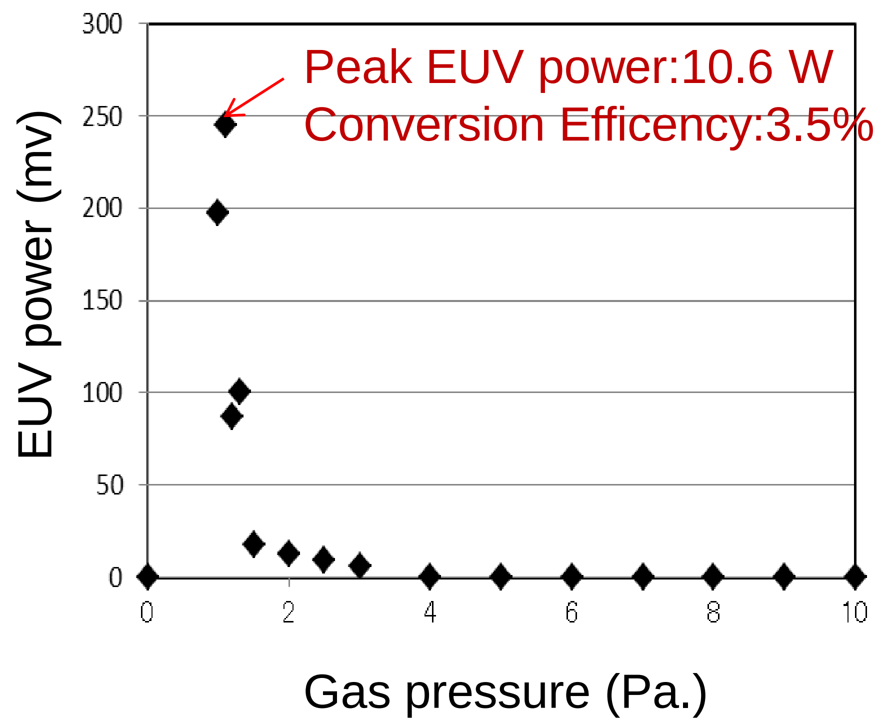
EUV Output Power by Microwave Plasma

(a) Time behaviors of EUV output

Frequency:100Hz



(b) EUV power vs. gas pressure



Summary and Conclusions

＜13.56 MHz RMF Plasma＞

- Smaller plasma of the diameter 1-1.5cm produces 13 W EUV for the net input power 1.6 kW, and the conversion efficiency is 0.8%.
- The extrapolation of the present data indicates 3kW input power will make 100 W @4π EUV power.

＜2.45 GHz Microwave Plasma＞

- The microwave produces the hot plasma with the diameter about 1.5 mm in the quartz tube.
- The plasma emits 10.6 W EUV at the peak by 300 W input power during 200 μsec.
- The conversion efficiency is achieved to be 3.5 %.

Thank you for your attention.